

Rarefied Solids: Aerogel Production in Low Gravity

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Research Summary

Since the renewed interest in low-density materials and aerogels in the 1980's, many investigators have speculated on limits to producing new varieties of highly porous materials. However, as they form, such particle aggregates must grow more tenuous and rarefied as they enlarge. In the presence of gravity, the few particle linkages and overall weight of the solid is self-limited. For rarefied solids made up of more than 10^4 particles, collapse or restructuring is imminent theoretically, and hence minimum achievable solid densities are set by the object's own weight. It is estimated that in unit gravity no rarefied solid can be stably created having a density less than 10^4 times the density of its constituent particles. The mathematical ideal (called Menger's Sponge, fig. 30) is a solid with infinite surface area and zero volume—in essence, a new kind of matter (a gelled aerosol) much akin to frozen smoke. On Earth, however, large single blocks of such low-density materials collapse, compress, or sag into condensed pancakes under their own weight. For these reasons, it is desirable to consider a mechanism for enlarging the observable window for aerogel growth. During aggregation and gelation of silica, gravity acts destructively to limit both the observable sizes of aggregates and to compact or densify the structure (lower its fractal dimension). The project aim therefore was to test fundamental aggregation phenomenon in a gravity field for the purposes of optimizing aerogel

production. As a result of the present airplane experiments which provided reduced gravity, aggregates of hydrophobic silica particles showed enlarged sizes (two orders of magnitude) and a more rarefied structure with higher internal surface area (40 percent lower “fractal dimension” varying from 1.45 in low gravity (g) to 1.9 in high g, fig. 30). Material properties are calculated theoretically to scale strongly with gravity as the inverse square root, such that with all other variables remaining constant, a million-fold reduction in gravity results in a 1,000-fold change in expected material properties. This change predicts novel aerogel and rarefied material behavior, including low conductivities for heat and sound, strong infrared absorption, and most spectacularly, an effective liquid-like surface tension in a solid. If realizable, such rarefied structures would allow reversible, noncatastrophic passage of large solid objects through tiny orifices. As derived here, the results are generic and not found to depend on the details of the gelation or growth process.

We identify the following milestones for the research: 1) First low gravity experiments and analysis of aggregate restructuring; 2) a follow-on Code U microgravity experimental proposal in collaboration with Lawrence Berkeley National Laboratories; 3) a follow-on Code X commercial project for Shuttle flights in collaboration with Aerojet Corporation (Sacramento, CA) and LBNL. Publication of CDDF results appeared in the international science journals.¹⁻³

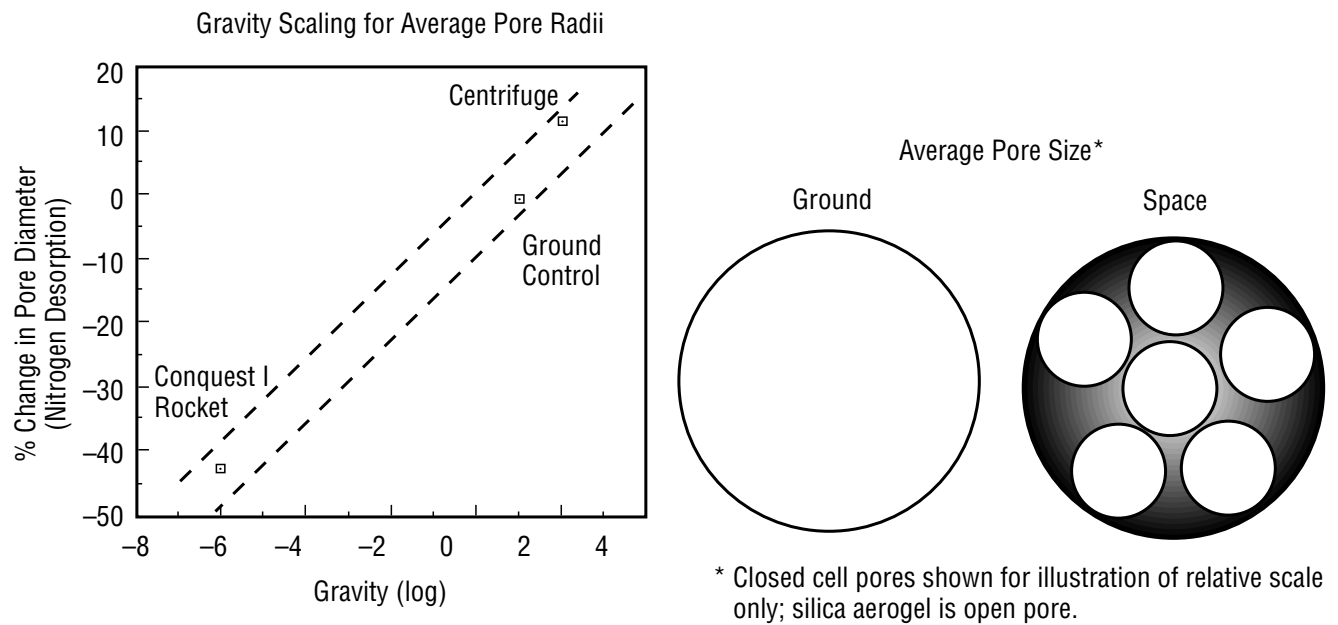


FIGURE 30.—Low-gravity aggregate enlargement for silica from KC-135 research results.

References

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